Insulation thin film and materials evaluation deposited on the copper substrate by DC discharge with directly- heated cathode and evaluation of the films

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Plasma CVD widely used in the manufacturing of the semiconductors is designed to make thin film deposition on the plane materials two-dimensionally. Most plasma sources commonly used there are not suitable to the uniform thin film deposition on the metal with a small cross section and a long length. In the present work, a novel plasma has been developed to deposit the insulation thin films on the fine copper wire using the DC discharge plasma with directly heated cathode. The substrate with small diameter and long length can be heated by the strong radiation from the heated cathode without any special heater. The thin film deposition has been carried out by this plasma and discussed by taking the analysis of the film materials into account.

The DC discharge plasma source consisted of the helically wound coils as a cathode made of 2% Thoriated Tungsten wire with a diameter of 0.5mm and the SUS mesh anode, which are placed coaxially inside the discharge tube. The cathode was directly heated by DC current of 10 A for each coil. The hydrogen gas was filled in the discharge chamber at the pressure of 50 mTorr. It is found that the ionization is mainly carried out near the helical coil because of enough a strong magnetic field induced by heater current and the discharge voltage around 30 V. The plasma density was a 10^{11}-10^{12} cm^{-3} on the axis of the chamber. The electron temperature was around a few eV.

The plasma was applied to make the Si-C or Si-N thin film deposition on the copper ribbon settled on the central axis of the chamber, where the hexamethyldisilane was mixed into the hydrogen. The thin film deposition was carried out as a function of the gas composition, gas flow rate and deposition time. The films are analyzed by FT-IR, SEM, XPS AES and so on. As a result, it is found that the structure of the thin film is hydrogenized amorphous Si-C which consists of Si-C and the Si-H. Moreover, physical properties of the film such as electric resistance, film flexibility, hardness and the high temperature oxidation were examined. The film has enough a high electric resistance as an insulator and hardness, while it has a shortage not sufficient flexibility for the application as insulated wire. The deposition rate of Si-C or Si-N thin film was found to be comparable with typical data given by the ECR plasma or the hot wall method.

In conclusion, it was proved that the present plasma is applicable to produce the insulated cupper wires with high hardness and anti-oxidization.